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Washington, D. C. 20231

NEW APPLICATION TRANSMITTAL

Transmitted herewith for filing is the patent application of:

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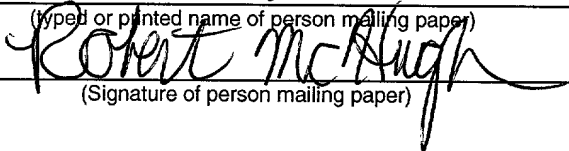
For: RADIO NETWORK ROUTING APPARATUSEK673490709US

Certification Under 37 CFR 1.10

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Robert McHugh

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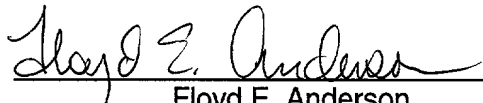
Attorney's Docket No. 99-432

Enclosed are:

[18] pages of specification and cover sheet
[6] pages of claims
[1] page of abstract
[7] sheets of formal drawings.
[3] pages of declaration and power of attorney.
[4] pages of assignment and assignment recordation form
[2] pages of information disclosure statement
[2] page of form 1449
[12] references
[1] return postcard

CLAIMS AS FILED				
	NUMBER FILED	NUMBER EXTRA	RATE	BASIC FEE \$690.00
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- [x] Please charge my Deposit Account No. 07-2339 in the amount of **\$924.00**. **This transmittal letter is submitted in duplicate.**
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UNITED STATES PATENT APPLICATION

OF

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and William S. PASSMAN**

FOR

RADIO NETWORK ROUTING APPARATUS

5

TITLE OF THE INVENTION

RADIO NETWORK ROUTING APPARATUS

BACKGROUND OF THE INVENTION10 1. Field of the Invention

The present invention relates to a radio network routing apparatus, and more particularly, to a protocol which reduces the amount of protocol traffic in mobile network routing.

2. Description of Related Art

15 Mobile networks typically use radios to communicate, but such radios are relatively slow data paths, as compared to wired networks or networks connected with fiber-optics.

In computer networks, the Open Shortest Path First (OSPF) routing algorithm is used for synchronizing the communication information in a computer network. The OSPF routing protocol, is a type of link-state protocol. A detailed discussion of link-state routing, including the OSPF protocol is included in Chapter 5 of Routing in Communications Networks by Martha Steenstrup and Chapter 5.2.2 of Computer Networks by Andrew S. 20 Tanenbaum. OSPF provides a method of synchronizing databases in computer network "routers." In OSPF, the router periodically advertises information describing its own database data (also referred to, herein, as link state data) to a

5 neighboring router and includes a sequence number that the
neighboring router can use to detect old or duplicate
advertisements. The router increases the sequence number when
it originates a new version of the advertisement. Thus, a
larger sequence number signifies a more recent advertisement.
10 The OSPF routing algorithm is also described in U.S. Patent No.
5,913,921 (Tosey et al.) and U.S. Patent No. 5,881,246 (Crawley
et al.).

Mobile networks have been unable to use standard OSPF protocols
to exchange internet routes and addresses. This is primarily
15 due to the fact that OSPF protocols require constant route
discovery through the use of HELLO messages. HELLO messages
are packets of information dispersed by each node throughout
the network to determine network topology. This HELLO traffic,
alone, can potentially utilize all of the message capability
20 (also referred to, herein, as "bandwidth") of a mobile
network having numerous nodes.

For example, a network consisting of four radio nodes (i.e.,
NODE A, NODE B, NODE C, AND NODE D) would generate several
HELLO messages. NODE A would send a HELLO message to each of
25 NODES B, C, and D; NODE B would send a HELLO message to each of
NODES A, C, and D; NODE C would send a HELLO message to each of
NODES A, B, and D; and NODE D would send a HELLO message to
each of NODES A, B, and C. Each such HELLO message sent by a

5 radio node must be answered with a reply HELLO message. Thus,
the resulting number of HELLO messages (HM) for a network with
N nodes can be determined by the following formula:

$$HM = N \times (N - 1) \times 2$$

10 Accordingly, a network with four nodes would generate 24 HELLO
messages. A network of 100 nodes would produce 19,800 HELLO
messages. Clearly, the generation of so many HELLO messages in
OSPF protocols has made the use of such protocols in mobile
networks unfeasible.

15 **SUMMARY OF THE INVENTION**

Among the several objects of the present invention, is to
reduce the amount of protocol traffic and, thereby, reduce
bandwidth usage. Another objective of the present invention is
to keep protocol messages as short as possible.

20 According to a first aspect of the present invention, each
router in a radio network having a plurality of routers
comprises a memory storing a routing table, and a receiver for
receiving link state information from the network. A processor
is provided for (i) determining, responsive to the received
25 link state information forwarded to the router, a status of
connections in the network, (ii) generating network topology
information based on the determined connection status

5 information, (ii) placing the generated network topology
information in said routing table, and (iv) transmitting the
network topology information in the routing table to at least
one other router in the network.

According to a second aspect of the present invention, a method
10 of distributing network topology information in a radio network
that includes a plurality of routers comprises the steps of
receiving link state information of the network that is
forwarded to each router; determining connections of devices in
the network in the receiving router responsive to the received
15 link state information forwarded to the router; and collecting
the determined device connection information to generate
network topology information in the receiving router. The
generated network topology information is placed in a routing
table of the receiving router, and the network topology
20 information is retrieved from the routing table.

According to a third aspect of the present invention, a routing
system in a radio network having plural routers comprises a
plurality of routers each including a receiver for receiving
link state information from the network in a message issued to
25 the plurality of routers. Each router also includes a
processor, responsive to the received link state information,
for (i) determining router connection information in the
network, (ii) collecting the determined router connection

5 information (iii) generating network topology information from
the collected router connection information, (iv) storing the
generated network topology information in a routing table, and
(v) retrieving the network topology information in the routing
table and forming it into a link state message to be broadcast
10 to at least one other router in the network.

According to a fourth aspect of the present invention, a
computer executable software code stored on a computer readable
medium is used for distributing network topology information in
a radio network that includes a plurality of routers. The code
15 comprises code for receiving link state information of the
network that is forwarded to each router; code for determining
connections of devices in the network in the receiving router
responsive to the received link state information forwarded to
the router; and code for collecting the determined device
20 connection information to generate network topology information
in the receiving router. Code is included for placing the
generated network topology information in a routing table of
the receiving router, and code is provided for retrieving the
network topology information from the routing table.

25 The foregoing and other objects, advantages, and features of
the present invention will become more apparent from the
following detailed description of the preferred embodiments

5 taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a mobile communications station.

Fig. 2 is a diagram illustrating a radio network configuration in accordance with the present invention.

10 Fig. 3 is a diagram illustrating routing tables for each router in the radio network of Fig. 2.

Fig. 4 is a flow chart illustrating the routing method of the present invention.

15 Fig. 5 is a diagram illustrating a "backbone" network of the present invention.

Figs. 6A and 6B are diagrams of a packet radio network with and without a designated router.

Fig. 7 is a flow chart of the ROSPF processing method.

20

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention relates in substantial part to a radio open shortest path first (ROSPF) protocol in mobile networking routing. In particular, this protocol (which can be used in
25 Intranet routing) involves dramatically reducing the amount of

5 protocol traffic and shortening the length of each protocol message. The reduction in protocol traffic facilitates the use of OSPF protocols in mobile networks.

Typically, HELLO messaging is the only way that the radio learns about other nodes in the system. However, the current invention does not require such extensive messaging. Rather, the OSPF protocol utilizes the current forwarding table of a radio node to learn about the other nodes in the system. The mobile routing protocol initiates link state flooding every second or so in a controlled manner to determine the connectivity topology of the network. Flooding is known to those of ordinary skill in the art, for example, as described in Steenstrup's Routing in Communications Networks. The flooding procedure is used for distributing link-state advertisements (LSA) (also referred to, herein, as link-state packets, LSP) throughout the routing domain. When the connectivity of the network changes, a new LSA describing the change must be created and flooded to all of the other nodes. There is no need for reply messaging.

The preferred embodiments will be described with respect to a wireless mobile communications station and to a network formed by a plurality of similar mobile stations. However, the present invention is not limited to the wireless mobile communications field. Instead, the invention is applicable to

5 many other types of networks, including cellular telephone systems, wireless metropolitan area networks, and so forth.

Figure 1 depicts a wireless communications station 2. The mobile station 2 includes a central processing unit (CPU) 3, a memory 4 (suitable for storing computer executable software
10 therein), a power supply 5, a transceiver 6 (e.g., a transmitter and a receiver), RAM 7, and ROM 8. Alternatively, the mobile station 2 may include more than one transmitter and/or more than one receiver. The mobile station 2 can also include an Ethernet interface, as well as other interfacing
15 ports. With these arrangements, the mobile station 2 is able to simultaneously communicate with more than one station. Communication with multiple stations can occur, for example, through different channels (or "communication links"), and/or by transmitting specific identifying information (or "coded
20 information") for each intended source or target.

Figure 2 is a schematic diagram of radio nodes in a wireless network according to the present invention. Five routers 10, 12, 14, 16, and 18 comprise the wireless network. Established channels or data communication links connecting the various
25 routers are designated by reference characters 20-26. The reference characters 20-26 also represent the cost of communicating along each respective channel (i.e., the cost of sending data traffic over each link). For example, the cost of

5 sending data traffic from node A to node B is 20.

While Figure 2 illustrates a particular interconnection of the various stations shown, it should be understood that this configuration of connections is not pre-determined and that other patterns of connections might easily arise in accordance with the present invention. Moreover, the pattern of connections can change during operation, both to accommodate the introduction of new stations and to allow for the withdrawal or movement of one of the nodes. The mode of operation of each router is controlled by an embedded microprocessor (e.g. the CPU) and the method of operation described herein is intended to be implemented automatically by the programming of the microprocessors.

Figure 3 is illustrative of the routing tables for each node in the network. Upon collecting the network topology information, each router builds a routing table (stored in memory) containing the acquired data. The routing table includes information such as the identity of the relevant router, a list of the router's operational links, the cost of each operational link, the identity of the node to which the router connects, and other such information.

The routing domain for the network in Figure 2 is displayed in Figure 3. The routing tables 101, 121, 141, 161, and 181

5 correspond to routers 10, 12, 14, 16, and 18, respectively.

The routing table 101 for router 10 (radio node A) advertises three active interfaces: one connecting to router 12 (node B) with a cost of 20, one connecting to router 14 (node C) with a cost of 24, and one connecting to router 18 (node E) with a
10 cost of 23.

Numerous other categories of information may be stored in these routing tables. For example, the sequence number, which is used to determine the most up-to-date instance of data in the routing table, can be stored. Additionally, the age of a
15 routing table can be stored so as to indicate when defunct data should be discarded and when the radio node should refresh its router. Another helpful type of data to be stored is the checksum of an advertisement's contents which assists in guarding against data corruption.

20 Adding more detailed and voluminous data in the routing table can facilitate more sophisticated routing-table calculations which are used for efficient message forwarding in a mobile network.

The topology information is collected by the routing protocols
25 using minimum bandwidth, so that it does not need to be collected again by ROSPF or any type of HELLO messaging.

In the overall method, shown in Figure 4, each radio node is

5 activated initially by the POWER ON step S1. A delay of random duration, e.g. from 1 to 60 seconds, is provided as indicated in step S2. After the delay, the router executes the receiving step S3 for receiving link state information of the network that has been forwarded to the router.

10 Subsequently, the determining step S4 is activated and is responsive to the received link state information forwarded to the router for determining connections in the network. If there are other accessible nodes in the network (step S5), then the network connection information is collected by the
15 collecting step S7 and placed in the routing table in the placing step S8.

However, if there are no accessible nodes in the network, then the controlling step S6 is executed. The controlling step S6 determines how often the router will attempt to gather and
20 distribute network topology information. The controller can be programmed so that it controls the frequency of this procedure based on a myriad of factors. For example, the flooding can occur periodically at regular intervals, e.g. every minute, every 10 minutes, every hour, etc. The controller can also
25 activate this procedure in response to a significant event, such as when a neighboring node leaves or joins a network.

In the case wherein there are other accessible nodes in the

5 network and the data regarding these other nodes has been
stored in the routing table, a determination is made in step S9
regarding whether there are messages that need to be forwarded
to other nodes in the network. If the response to the inquiry
in step S9 is affirmative, then the retrieving step is executed
10 in step S10. Once that is complete, the controlling step is
executed in step S6. Based on the frequency with which the
controlling step is activating the overall procedure, the
process will begin again at the appropriate time.

However, if the response to the inquiry in step S9 is negative,
15 then resignation from the network occurs in step S11.

The ROSPF protocol has a functionality like the OSPF protocol.
However, in the ROSPF protocol, the "behavior" of the router
has been modified to eliminate enormous quantities of traffic
that would otherwise "clog" a large, multi-hop, low bandwidth
20 network, such as a packet radio network. ROSPF allows a large
packet radio network to become an internet protocol (IP)
backbone. As explained in further detail below, the ROSPF
protocol defines a parasitic relationship between two routing
protocols.

25 Figure 5 illustrates a backbone network that is arranged using
OSPF. The purpose of OSPF is to compute routes to IP networks.
In an initial step of OSPF, each router discovers its

5 neighbors. This is accomplished using the Hello protocol. It not only discovers neighbors but it also elects a "spokesperson" for the network called the designated router.

Secondly, each router constructs Link State Packets (LSPs) that contain the IDs and costs of the links to its neighbors.

10 Next step, the LSPs are transmitted to all the other neighbors, via the designated router using the link state flooding process. Each router stores the most recently generated LSP from each of the other routers, and creates a link state database. The link state database defines the topology (i.e.,
15 the configuration of the nodes and links) of the network and the cost of each link.

Finally, each router uses the link state database to compute routes to each destination.

The network illustrated in Figure 5 depicts a backbone network
20 created by OSPF. The backbone network provides the means for connecting IP networks X, Y, and Z. Router 193, which is depicted as the designated router, exchanges LSPs with the other two routers. Router 191 and router 192 do not have the capability to exchange LSPs with each other directly.

25 However it is feasible to use OSPF to create an IP backbone only when the number of OSPF routers that are attached to the

5 backbone network is small in comparison to the bandwidth of the
backbone network. Otherwise, in a case when the backbone
network is a large-scale packet radio network with limited link
bandwidth and a large number of nodes, then the OSPF protocol
and LSP traffic will exceed the capacity of the backbone
10 network.

ROSPF uses two primary mechanisms to either reduce or eliminate
these traffic loads.

The first mechanism is the elimination of the hello protocol
that is an aspect of OSPF. When the backbone network is a
15 packet radio network with an Intranet routing algorithm, and
every router in this network is running OSPF, then the Intranet
routing algorithm already has information that is equivalent to
the information that would be obtained by the OSPF hello
protocol. In this particular case, the hello protocol is
20 redundant and can be eliminated. However, this redundancy
would not exist if the backbone network consists of, for
example, an Ethernet LAN or an X.25 network. Accordingly,
ROSPF can primarily be used in conjunction with a network that
has an Intranet routing algorithm. The Intranet is an
25 independent entity that provides information to the OSPF
protocol, while ROSPF defines the parasitic relationship
between the Intranet and the OSPF protocols.

5 The second mechanism employed by ROSPF is the elimination of designated routers. Designated routers define the way that link state packets are flooded. They flow from a given router to the designated router and then fan out to reach all the other routers. In a large scale network, the flow of link
10 state packets through the designated router can make it a "hot spot" as illustrated in Figure 6A, wherein designated router 202 denotes the hot spot of the network. In a packet radio network with an Intranet routing algorithm, the backbone network topology includes a connected graph, as shown in Figure
15 6A. The Intranet forwarding tables define the routes that packets take through the network.

However, in ROSPF there is no designated router and IP LSPs are exchanged by each node with its Intranet neighbors. In essence, IP link state packets flow through the network like a
20 rumor in a community, or a ripple in a pond. As such, ROSPF eliminates the designated router hot spot.

The ROSPF/Intranet interface enables the Intranet to provide ROSPF with two lists: the next-hop list and the census list. The next-hop list is used to define OSPF adjacencies (i.e.,
25 one-hop radio neighbors). The census list is used identify all radio routers on the network. Deltas (differences in these lists) are used to quickly detect deceased routers.

- 5 The Rospf processing method is illustrated in Figure 7. In step S20, Rospf queries the Intranet. The next-hop list is processed in step S21. In this step the network is examined for deltas to build ospf adjacencies with new neighbors and terminate ospf adjacencies with missing neighbors.
- 10 The census list is processed in step S22. The census list defines all of the nodes that are currently in the network. The deltas are computed by comparing the new list with the old list. Rospf ignores the new nodes, but identifies the nodes that have "dropped off" the list. For each node that is no
- 15 longer on the list, Rospf marks the IP link-state that the node advertised as irrelevant and computes an updated IP forwarding table. Census list processing allows Rospf to quickly detect "dead" routers.
- The Rospf process is cyclical and begins again at step S20.
- 20 The frequency of the Intranet queries can be periodic, predetermined, or set by any number of variables.

While the present invention has been described with respect to what are presently considered to be the preferred embodiments, it is to be understood that the invention is not limited to the

25 disclosed embodiments. The present invention is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

5 For example, the radio network has been described as having
five radio communication nodes (Figures 2 and 3). However, the
network can include any number of radio and wired links. Also,
as will be appreciated by those skilled in the art, the methods
and control logic, as described herein, can be embodied in a
10 programmable computer or computer executable software that is
stored on computer readable media, for example, on a floppy
disk, RAM, ROM, a hard disk, removable medium, flash memory,
memory sticks, optical medium, magneto-optical mediums, etc.

15 Additionally, the described methods, structure, and functions
are directed to wireless mobile communications stations that
automatically configure themselves in a mobile communications
network, with each mobile station directing its respective
affiliation. However, control of such configurations could be
centralized to cluster heads, for example, which would then
20 direct affiliation on a network level to optimize the network.
Furthermore, the above methods and structure are not limited to
wireless communications networks, but may be employed by any
system wherein there is an Intranet protocol to interface with
the ROSPF protocol.

5

WHAT IS CLAIMED:

1. A router for a radio network that includes a plurality of other routers, said router comprising:

a memory storing a routing table;

10 a receiver for receiving link state information from the network; and

a processor for (i) determining, responsive to the received link state information forwarded to the router, a status of connections in the network, (ii) generating network topology information based on the determined connection status information, (ii) placing the generated network topology information in said routing table, and (iv) transmitting the network topology information in the routing table to at least one other router in the network.

20

2. A router according to Claim 1, wherein the processor transmits the network topology information to the at least one other router in the network at a predetermined cycle.

25

3. A router according to Claim 1, further comprising a transmitter for transmitting a message including the network topology information retrieved from said routing table.

5 4. A method of distributing network topology
information in a radio network that includes a plurality of
other routers comprising the steps of:

 receiving link state information of the network that
is forwarded to each router;

10 determining connections of devices in the network in
the receiving router responsive to the received link state
information forwarded to the router;

 collecting the determined device connection
information to generate network topology information in the
15 receiving router;

 placing the generated network topology information in
a routing table of the receiving router; and

 retrieving the network topology information from the
routing table.

20

 5. A method according to Claim 4, wherein the
network topology information is generated periodically.

 6. A method according to Claim 4, further
25 comprising the step of transmitting a message by the receiving
router including the network topology information retrieved
from the routing table.

 7. A method according to Claim 4, wherein the link

5 state information is transmitted to the plurality of routers at predetermined times.

8. A method according to Claim 4, wherein the link state information is forwarded to the plurality of routers
10 periodically.

9. A routing system in a radio network having plural routers, comprising:

a plurality of routers each including:

15 a receiver for receiving link state information from the network in a message issued to the plurality of routers;

a processor in each router, responsive to the received link state information, for (i) determining router connection information in the network, (ii) collecting the
20 determined router connection information (iii) generating network topology information from the collected router connection information, (iv) storing the generated network topology information in a routing table, and (v) retrieving the
25 network topology information in the routing table and forming it into a link state message to be broadcast to at least one other router in the network.

10. A routing system according to Claim 9, wherein each processor periodically generates the network topology

5 information.

11. A routing system according to Claim 9, further
comprising a transmitter in each router for transmitting the
link state message including the network topology information
10 retrieved from the routing table.

12. A routing system according to Claim 11, wherein
the transmitter transmits the link state information message to
a plurality of routers at predetermined times.

15 13. A routing system according to Claim 11, wherein
the transmitter periodically broadcasts the link state
information message to the plurality of routers.

20 14. A routing system according to Claim 9, wherein
the transmitter transmits the link state information message to
the plurality of routers after its corresponding receiver
receives the link state information from the network.

25 15. Computer executable software code stored on a
computer readable medium, the code for distributing network
topology information in a radio network that includes a
plurality of routers, the code comprising:

code for receiving link state information of the

5 network that is forwarded to each router;

code for determining connections of devices in the network in the receiving router responsive to the received link state information forwarded to the router;

10 code for collecting the determined device connection information to generate network topology information in the receiving router;

code for placing the generated network topology information in a routing table of the receiving router; and

15 code for retrieving the network topology information from the routing table.

16. A router for a radio network that includes a plurality of other routers, said router comprising:

20 means for storing a routing table;
means for receiving link state information from the network;

means, responsive to the received link state information forwarded to the router, for determining a status of connections in the network;

25 means for generating network topology information based on the determined connection status information;

means for placing the generated network topology information in said routing table; and

means for transmitting the network topology

5 information in the routing table to at least one other router
in the network.

17. A routing system in a radio network having
plural router, comprising a plurality of routers, comprising a
plurality of router, each router including:

10 means for receiving link state information from the
network in a message issued to the plurality of routers;

means for determining router connection information
in the network;

15 means for collecting the determined router connection
information;

means for generating network topology information
from the collected router connection information;

means for storing the generated network topology
information in a routing table; and

20 means for retrieving the network topology information
in the rating table and forming it into a link state message to
be broadcast to at least one other router in the network.

5

ABSTRACT

In a radio network having plural routers (10, 12, 14, 16, 18), each router includes a routing table (101, 121, 141, 161, 181). Link state information of the network that has been forwarded to the router is received and used to determine the connections in the network. The determined network connections are collected to generate network topology information which is placed in the routing table (101, 121, 141, 161, 181). The network topology information is retrievable for inclusion in messages forwarded by the receiving router.

15

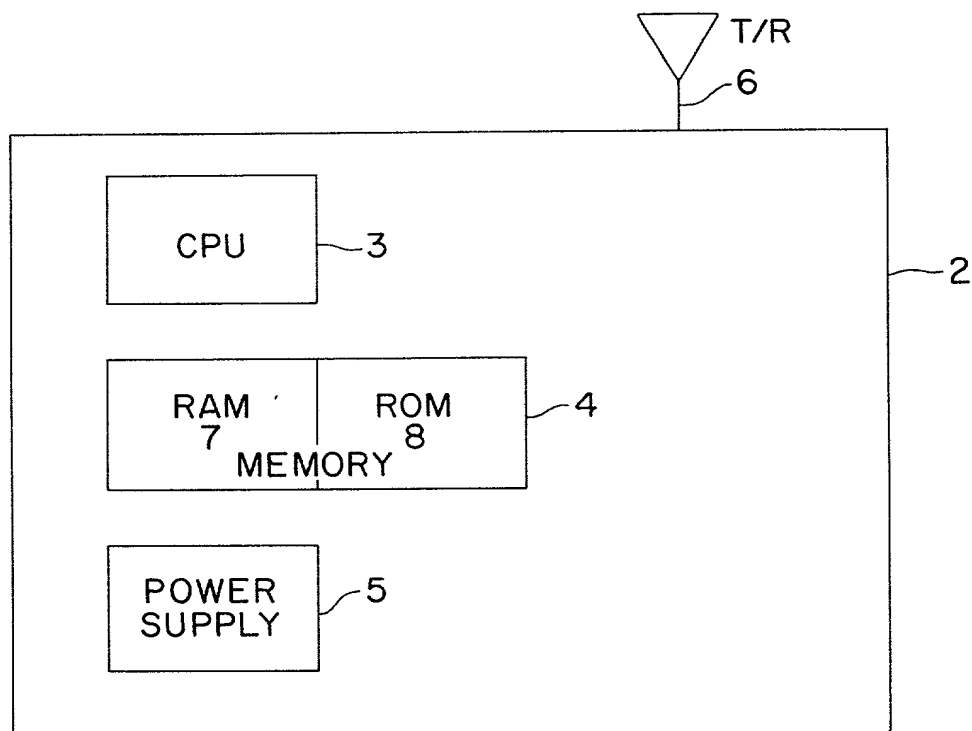


FIG. 1

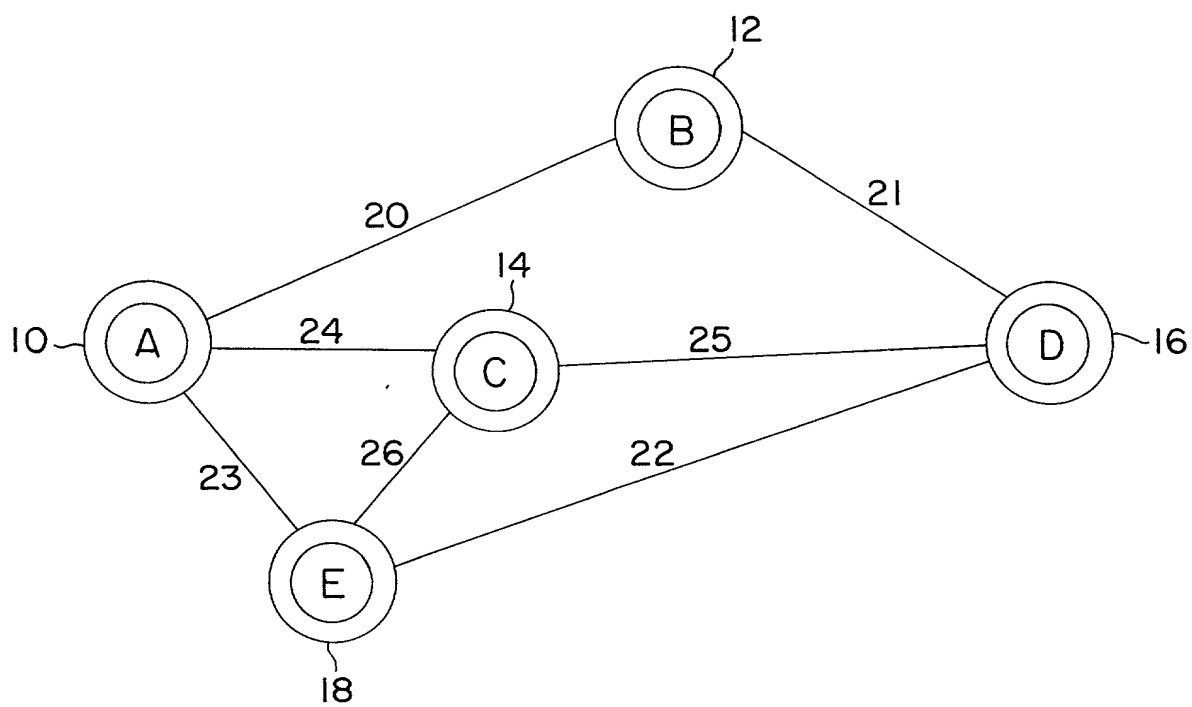


FIG. 2

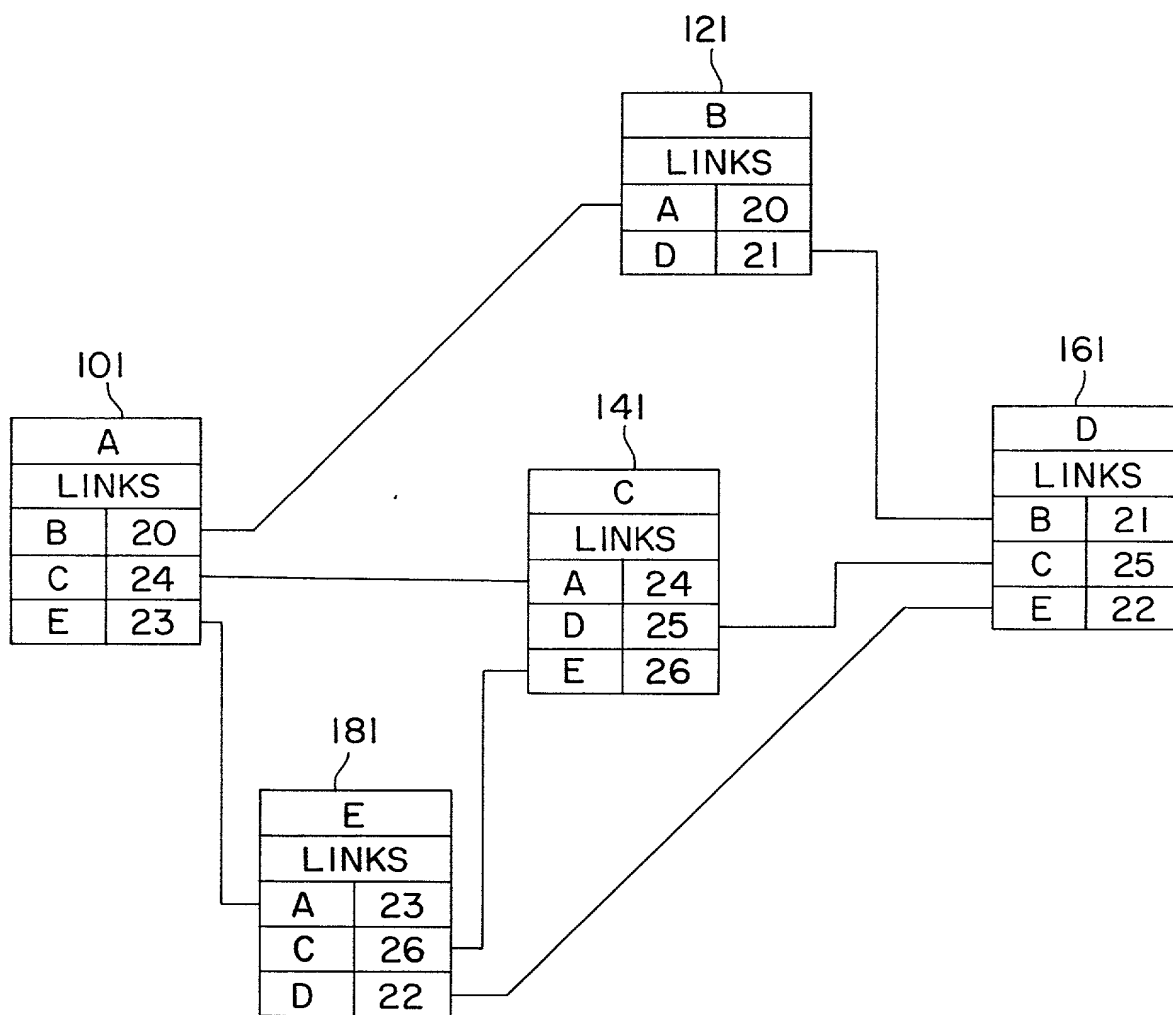


FIG. 3

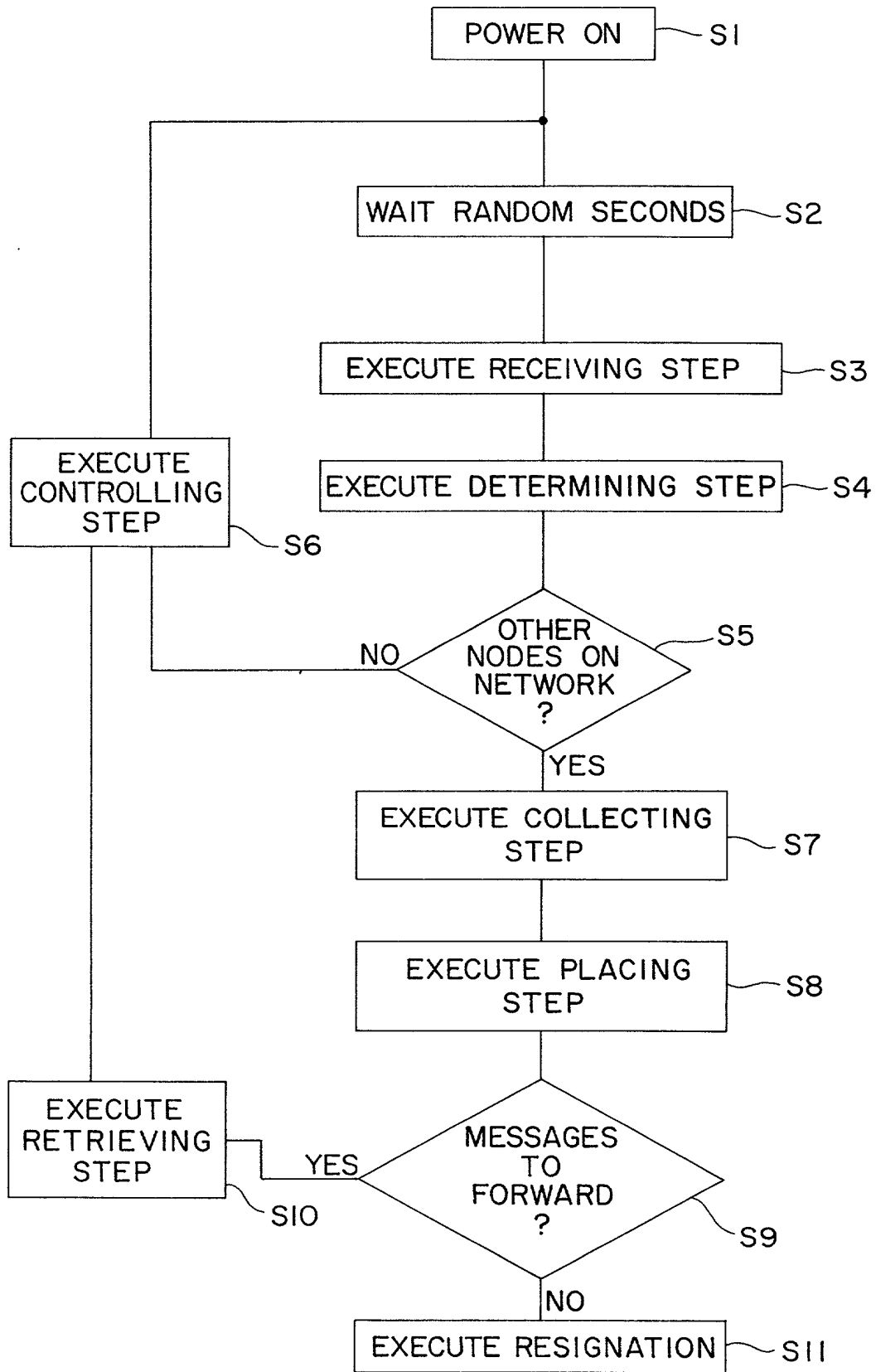


FIG. 4

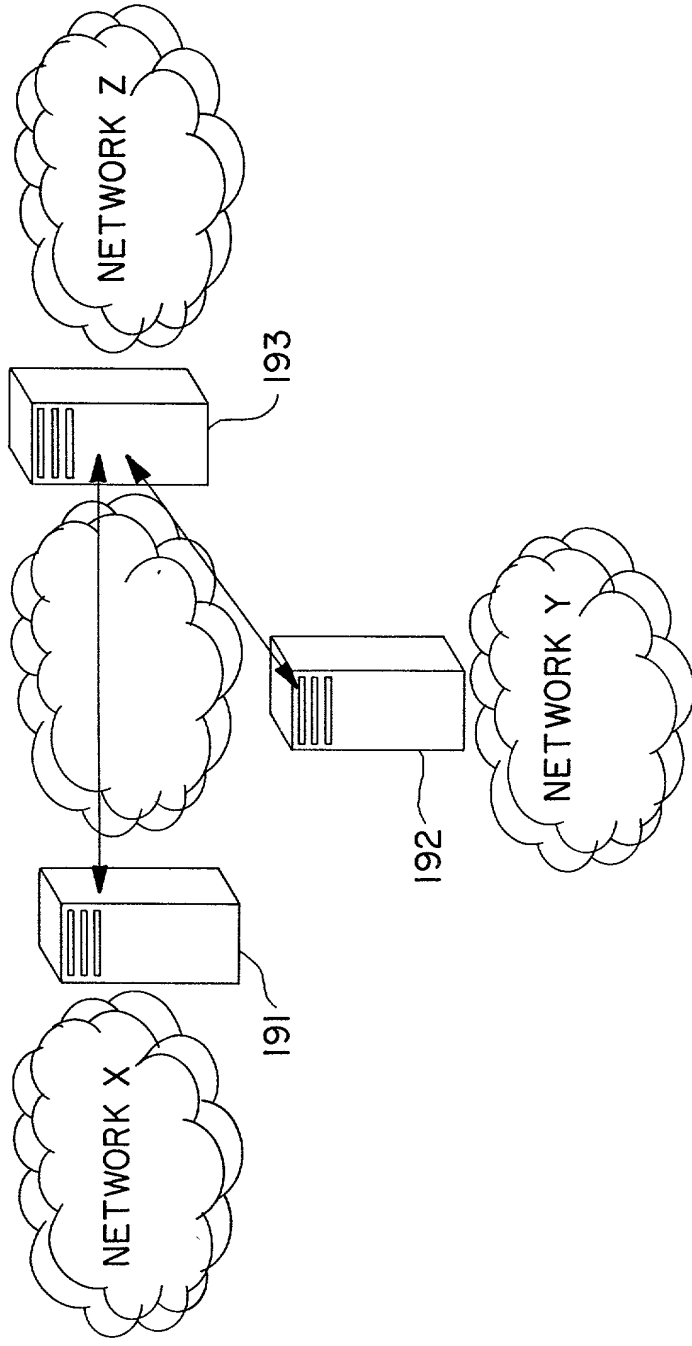


FIG. 5

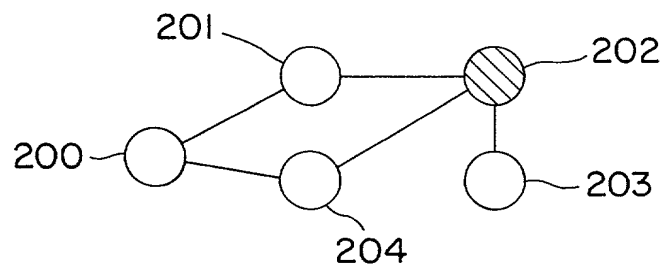


FIG. 6A

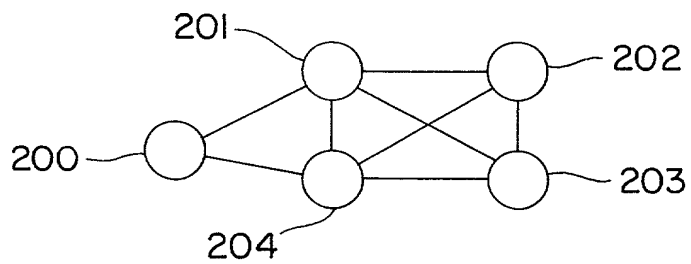


FIG. 6B

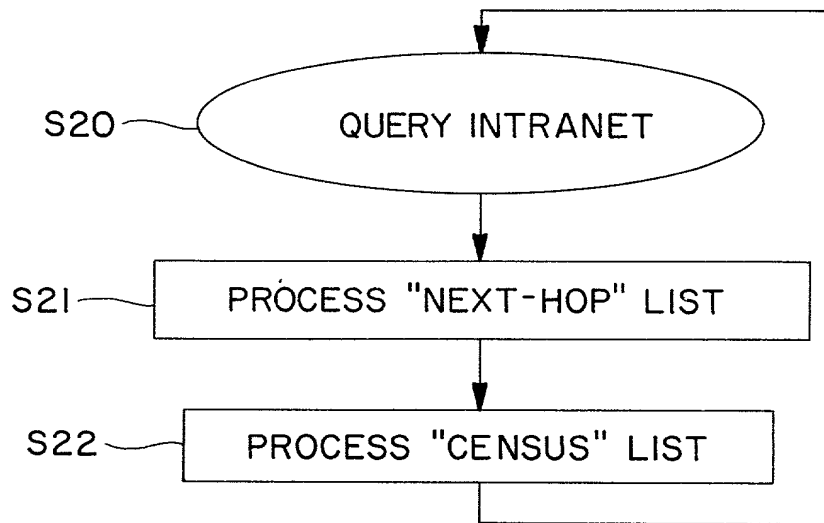


FIG. 7

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

Docket No. 99-432

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled:

RADIO NETWORK ROUTING APPARATUS

the specification of which [X] is attached hereto. [] was filed on
as Appln. Serial No. _____

And was amended on _____

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed

[] Yes [] No

(Number)

(Country)

(Day/Month/Year filed)

I hereby claim the benefit under Title 35, United States Code, 119(e) of any United States provisional applications(s) listed below.

(Application Number)

(Filing Date)

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date for this application:

(Appln. Serial No.)

(Filing Date)

(Status—patented, pending, abandoned)

Docket No. 99-432

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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